Road to the 2002 Code

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Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

On November 1st, proposals for changes to Article 690 of the 1999 *National Electrical Code* were received at the National Fire Protection Association (NFPA). These proposals represent a coordinated input from more than 30 people in the PV industry (The Photovoltaic Power Industry Forum). If these proposals are accepted in either an "as submitted" or edited form, they will appear in the 2002 *National Electrical Code (NEC).* The proposals and the substantiation for each are presented below.

The actions of the *NEC* Code-Making Panels on these proposals will be available from the NFPA as a Report on Proposals due out in late July 2000. Comments from anyone—including the general public—will be received at NFPA until October 27, 2000. All proposals were submitted by the Photovoltaic Power Industry Forum; Ward Bower, Chairperson; John Wiles, Secretary.

Figure 690.1(A) Identification of solar photovoltaic system components
Proposal: In this figure, the Blocking Diodes have been drawn incorrectly as an arrow with a line on top. They need to be redrawn with the correct symbol for an electronic diode. See Figure 690-7 in the *NEC Handbook.*

Substantiation: Corrects drafting error.

Figure 690.1(B) Identification of solar photovoltaic system components in common system configurations
Proposal: In the Stand-Alone System figure, label the unmarked box at the bottom of the figure: "Energy Storage."

Substantiation: This label was accidentally left off the submission for the 1999 *NEC.*

690.2 Definitions
Proposal: Add the following definition:

Diversion Charge Controller. Equipment that regulates the charging process of a battery by diverting power from energy storage to direct-current or alternating-current loads or to an interconnected utility service.

Substantiation: Required to define devices used in this article.

690.2 Definitions
Proposal: Add the following definition:

Bipolar Photovoltaic Array. A photovoltaic array that has two outputs, each having opposite polarity with respect to a common reference point, sometimes called a center tap.

Substantiation: Required to define devices and connections used in this article.

690.2 Definitions
Proposal: Delete the definition of System Voltage and replace with the following:

Photovoltaic Systems Voltage. The direct current (dc) voltage of any photovoltaic source or photovoltaic output circuit. For bipolar or multiwire installations including 2-wire circuits connected to bipolar systems, the PV systems voltage shall be the highest voltage between any two dc conductors.

Substantiation: Defines terms used in this article and updates terminology.

690.4(B) Conductors of Different Systems
Proposal: Delete the text in this section and replace with the following:

Photovoltaic (PV) source and PV output circuits having disconnects from the PV energy source shall be permitted in the same raceway or junction box with circuits from non-photovoltaic systems. Photovoltaic source and PV output circuits shall be permitted in the same raceway or junction box with other circuits from the same PV system.

Substantiation: The intent of the basic requirement is to prevent PV source and output circuits that may normally be energized during daylight periods from being in the same raceway with circuits of other electrical systems that are unrelated to the PV system. In many cases there are no disconnects in these PV circuits and they are always energized during daylight hours. Repairs and operations on these "other system" circuits might be affected by the always-energized PV circuits. "Other system" circuits include ac grid power conductors, telecomm circuits, or radio frequency cables. The term "other systems" was not clear, and the text has been revised accordingly. The text was also revised from the negative to the positive.

The first sentence of the proposed addition allows same-raceway installations if the PV circuits have an available disconnect provision that can de-energize these PV circuits. These PV source and output circuits then become no different than any other circuit in a multiple circuit raceway.

The second sentence recognizes that persons working on any circuits associated with the PV system (inverter ac outputs, control circuits, etc.) will be aware of the nature of the PV source circuits and take proper precautions. It allows any circuits from the same PV system to be in the same raceway without restriction.

690.4(C) Module Connection Arrangement
Proposal: Delete the last two sentences from this paragraph.

They are: Sets of modules interconnected as systems rated at 50 volts or less, with or without blocking diodes, and having a

single overcurrent device shall be considered as a single-source circuit. Supplementary overcurrent devices used for the exclusive protection of the photovoltaic modules are not considered as overcurrent devices for the purpose of this section.

Substantiation: These sentences conflict with the requirement established by labels on listed photovoltaic modules for a series module protective fuse on each module or string of modules. The first sentence in this section establishes the safety requirement. The industry is now using source circuit combiners to meet the requirement.

The labeling requirements for modules are being coordinated with Underwriters Laboratories (UL) to indicate on the module label or in the instructions, the maximum number of modules that may be connected in parallel.

690.5(B) Disconnection of Conductors
Proposal: Revise the last sentence to read as follows:

Opening the grounded conductor of the array or faulted sections of the array shall be permitted to interrupt the ground-fault current path.

Substantiation: Corrects grammatical error in the 1999 *NEC.*

690.6(A) Photovoltaic Source Circuits
Proposal: Correct the spelling of "photovoltaic" in the second sentence

Substantiation: Corrects spelling error in the 1999 *NEC.*

690.6(D) Ground-Fault Detection
Proposal: Replace the existing text with the following:

Alternating current (ac)-module systems shall include a ground-fault detection device to reduce fire hazards. A single detection device shall be permitted for each system (one or more modules). That device shall detect ac ground faults, indicate the fault, and disconnect the alternating-current module(s) from the ac source.

Substantiation: Revised text requires the device and clarifies the requirement. The 1999 *NEC* did not require the device, only permitted it.

690.7(A) Maximum System Voltage
Proposal: Change the title of the section to:

(A) Maximum Photovoltaic System Voltage

And add the word "photovoltaic" in the first sentence between the words "maximum" and "system."

Substantiation: Clarifies the section and makes it consistent with new definitions and other sections of this article.

690.8(B)(1) Devices With Internal Current-Limiting
Proposal: Overcurrent protection for photovoltaic output circuits that supply devices that internally limit the current drawn from that photovoltaic output circuit shall be permitted to be rated at less than the value computed in 690.8(B). This reduced rating shall be at least 125% of the limited-current value. An overcurrent device in an assembly listed for continuous operation at 100% of its rating shall be permitted to be used at 100% of its rating.

Photovoltaic output circuit conductors shall be sized in accordance with Section 690.8(B).

Substantiation: This addition allows the use of a smaller overcurrent device than the calculation in 690.8(B) normally requires. The reduction is allowable because certain listed devices such as charge controllers and inverters can limit the maximum current that can be drawn from a source circuit.

The second sentence ensures that the overcurrent device will not be operated at more than 80% of its rating.

The final sentence ensures that the conductors are properly sized to handle fault currents from the photovoltaic source that could result from faults on the photovoltaic side of the overcurrent device.

690.9(C) Photovoltaic Source Circuits
Proposal: Add the following second paragraph:

The standard values of supplementary-type overcurrent devices allowed by this section shall have ratings in one-ampere increments from one to 15 amperes. Higher standard values shall comply with Section 240.6(A).

Substantiation: Article 240.6(A) sets standard values for class-type fuses. This Section allows listed supplementary-type fuses. Module-protection fuse requirements established by UL and the module label require fuses with ratings between 5 and 20 amps. For example, to increase the 8-amp required value of a module-protection fuse to the first standard value of 15 amps would create a safety problem. This proposal defines and requires that the proper fuse value be used.

690.9(E) Combined Photovoltaic Module and Source Circuit Protection
Proposal: A single overcurrent device shall be permitted to meet the conductor protection requirements established by Sections 690.8 and 690.9 and the photovoltaic module overcurrent protection requirements established by labels on the module.

Substantiation: UL instructions and labeling require that a series module-protection fuse be used to protect each module from reverse currents. In series-connected strings of two or more modules, only a single overcurrent device is required to protect all of the modules in the string. The rating of this overcurrent device is normally the same as or greater than the rating of the code-required overcurrent device to protect the module interconnection conductors. Frequently, a single overcurrent device can be used to meet both of these requirements.

690.9(F) Conductor Ampacity When Using Parallel-Connected Modules
Proposal: Where a single overcurrent device, allowed by Section 690.9(E), is used to protect a set of two or more parallel-connected module circuits, the ampacity of each of the module interconnection conductors shall not be less than the sum of (1) and (2).

(1) The rating of the single fuse.

(2) 125% of the short-circuit current from the other parallel-connected modules.

Substantiation: Under fault conditions, the individual module conductors will be required to carry currents through the fuse from batteries or other sources plus 125% of the short-circuit currents from the other modules.

690.14 Additional Provisions
Proposal: Delete the existing sentence and replace with: Photovoltaic disconnecting means shall comply with (A) through (C).

Substantiation: Photovoltaic source circuits have unique properties that are different from utility service entrances. The unnecessary reference to Article 230 causes some AHJs to require unnecessary or unsafe equipment. Article 690 contains all necessary requirements for disconnecting means. Section 690-14(C) is added in a separate proposal.

690.14(C) Grouping
Proposal: The photovoltaic disconnecting means shall be grouped with other disconnecting means for the system. A photovoltaic disconnecting means shall not be required at the photovoltaic module or array location.

Substantiation: To comply with the code requirements for grouping all disconnects of a power system in a single location, it is necessary to have the photovoltaic disconnecting means grouped with the other disconnecting means. Although photovoltaic modules and arrays may be located some distance away or on the roof, there is no requirement for a disconnect at the source because the source is energized in daylight whether or not the disconnect is opened.

690.31(B) Single-Conductor Cable
Proposal: Add USE-2 to the three acceptable cable types in the first sentence.

Substantiation: Many photovoltaic module installations operate at temperatures that require a 90°C, wet-rated, sunlight resistant single-conductor cable. USE-2 meets these requirements, is commonly available, and is the most appropriate cable for this application.

Table 690-31(C) Correction Factors
Proposal: Change the last two Fahrenheit (°F) temperatures as follows:

Change 141-149 to 141-158

Change 150-158 to 159-176

Substantiation: Corrects errors in the table

690.41 System Grounding
Replace the existing contents with the following:

For a photovoltaic power source, one conductor of a two-wire system with a system voltage over 50 volts and the reference (center tap) conductor of a bipolar system shall be solidly grounded or shall use other methods that accomplish equivalent system protection in accordance with Section 250.2(A).

Substantiation: Updates the terminology to be consistent with new definitions and definitions in the 1999 *NEC.* Moves the exception into the basic requirement. All equipment in the code is required to be listed so that 1999 *NEC* requirement for listed devices is not needed. The proposal also merges the FPN into the requirement to ensure that the device used is fully defined.

690.45 Size of Equipment Grounding Conductor
Proposal: Replace the existing paragraph with the following:

Where not protected by the ground-fault protection equipment required by Section 690.5, the equipment-grounding conductor for PV source and PV output circuits shall be sized for 125% of the PV-originated short-circuit currents in that circuit. Where protected by the ground-fault protection equipment required by Section 690.5, the equipment-grounding conductors for PV source and PV output circuits shall be sized in accordance with Section 250.122.

Substantiation: When Underwriters Laboratories (UL) recently listed a PV combiner enclosure, they determined that ground faults in PV source and output circuits can result in continuous currents from the PV array flowing through the equipment-grounding conductor even after all overcurrent devices have tripped. This determination indicates that the equipment-grounding conductor for these circuits should be able to carry the currents from the PV sources. These equipment-grounding conductors should be sized at only 125% of the short-circuit current (Isc) since the additional 125% derating for continuous operation is not required. The equipment-grounding conductor (sized at 125% Isc) might be one size smaller than the circuit conductors (sized at 156% Isc) in a few systems.

If the system has a Section 690.5 ground-fault protection device installed, then the interruption of the fault current will prevent these PV currents from flowing in the equipment-grounding conductor and the increased size is not necessary. In this case, the requirements of Section 250.122 are appropriate.

690.51 Modules
Proposal: Delete this section

Substantiation: These requirements duplicate the requirements established by UL Standard 1703 and are required on the labels of all modules. This section is no longer needed.

690.52 Alternating-Current Photovoltaic Modules
Proposal: Delete this Section

Substantiation: These requirements duplicate the requirements established by UL Standard 1703 and are required on the labels of all modules. This section is no longer needed.

690.55 Energy Storage
Proposal: Photovoltaic power systems employing energy storage shall also be marked with the information in (1) and (2).

(1) Maximum operating voltage including any equalization voltage

(2) Polarity of grounded circuit conductor

Substantiation: These additional markings will facilitate the inspection, maintenance, and operation of the system.

690.56 Exterior Location
Proposal: Any structure or building with a photovoltaic power system capable of acting as a Stand-Alone System shall have a permanent plaque or other label placed in a visible location on the exterior of the building or structure with the notice (1) and information (2). For structures with a utility service entrance, the label shall be located adjacent to the service entrance, exterior meter socket, or exterior utility disconnect.

(1) "This structure contains a Stand-Alone Electrical Power System"

(2) Location of system disconnects (PV, battery, and other energy sources).

Substantiation: Facilitates the rapid shut down of all power to a building in an emergency.

690.64(B)(5) Load Side
Proposal: Delete this section

Substantiation: With utility-interactive inverters, this section is not needed. Circuit breakers, used to conduct currents from a utility-interactive inverter into a load center, may be subjected to faults on the inverter side of the breaker. While the breaker may carry normal operating current in a reverse direction, any overcurrent tripping in a fault situation is in the normal forward direction.

Other sections of the code (not this one) may require clamping backfed breakers, but this is not necessary since these breakers, if removed while being used, immediately become de-energized or dead due to the de-energizing circuits in the connected inverter.

690.71(D) Nonconductive Cases
Proposal: Flooded, vented, lead-acid batteries with more than 24, 2-volt cells connected in series (nominal 48 volts) shall not use or be installed in conductive cases. Conductive racks used to support the nonconductive cases are permitted where no rack material is located within six inches of the tops of the nonconductive cases.

FPN: This requirement does not apply to any type of valve regulated lead-acid battery (VRLA) or any other types of sealed batteries that may require steel cases for proper operation.

Substantiation: Battery cases of flooded, lead-acid batteries made of steel or other conductive materials must be grounded to meet the requirements of this code.

Acid and dirt films on the tops of the cells created during the normal charging and equalizing processes form conductive leakage paths between the circuit conductors and the grounded cases. These leakage paths may lead to higher and higher fault currents that can result in fires and explosions.

Attempts to float or otherwise electrically isolate these conductive cases may result in a shock hazard between the cases and the grounded racks or conductive floor. Paint or other thin insulating films have not proven effective in isolating grounded cases.

Sandia National Laboratories has documented battery fires, explosions, and shocks to qualified service personnel over the last five years on battery systems employing metal cases.

The FPN is added for explanatory reasons. This proposal does not apply to any type of valve regulated lead-acid battery (VRLA) or any other types of sealed batteries that may require steel cases for proper operation.

690.71(E) Segmented Batteries
Proposal: Battery circuits, subject to field servicing, where there are more than 24, 2-volt cells connected in series (nominal 48 volts) shall have provisions for qualified persons to disconnect the series-connected strings into segments of 24 cells or less for service. Non-load-break bolted or plug-in disconnects are permitted.

Substantiation: Working on high-voltage strings of batteries is inherently hazardous, even for qualified persons. Breaking the strings into not more than 24-cell segments allows the individual cells or batteries to be serviced at voltages of 48 volts (nominal) or less. While it is optional with the servicing person to break the strings, the provisions for such disconnects should be required. Some battery systems are installed with welded inter-cell connections that cannot be disconnected without cutting cables.

The hazard is significantly reduced for batteries operating below 48 volts nominal. No problems have been documented using metal cased batteries at 48 volts nominal in forklift truck applications.

Some high-voltage sealed (VRLA) battery systems are sealed in a container at the factory and are not serviced in the field. They would not be subject to this requirement.

690.71(F) Floated Batteries for Maintenance Operations
Proposal: Battery installations where there are more than 24, 2-volt cells connected in series (nominal 48 volts) shall have a switched disconnect, accessible only to qualified persons, that ungrounds the battery electrical system for maintenance. This switch shall not unground the remainder of the PV electrical system. The use of a non-load break rated switch shall be permitted.

Substantiation: Battery systems, due to the presence of conductive acid films on batteries, are inherently hazardous to service. By allowing the qualified maintenance person to unground the battery, the hazards may be somewhat reduced even when protective clothing, proper tools, and correct procedures are used. Since it is generally acknowledged that a floated, high-voltage battery is safer for servicing, the requirement is mandatory.

The hazard is significantly reduced for batteries operating below 48 volts nominal and is not required for these lower-voltage systems.

690.71(G) Ungrounded Battery Systems
Proposal: On photovoltaic systems where the battery system consists of more than 24, 2-volt cells connected in series (nominal 48 volts), the battery system shall be permitted to operate with ungrounded conductors provided that conditions (1) through (4) are met:

(1) The photovoltaic array source and output circuits shall be solidly grounded.

(2) The dc and ac load circuits shall be solidly grounded.

(3) All main ungrounded battery input/output circuit conductors shall be provided with switched disconnects and overcurrent protection.

(4) A ground-fault detector and indicator shall be installed to monitor for ground faults in the battery bank.

Substantiation: This proposal permits high-voltage (above 48-volts nominal) battery systems to be operated in an ungrounded state if the listed conditions are met. Certain types of power processing equipment (inverters) can be designed for this type of operation. This proposal may be most likely applied on higher voltage (above 200 volts) systems. This ungrounded operation may increase long term reliability and fire safety in the system.

690.72(A) Diversion Charge Controllers–Independent Backup

Proposal: A photovoltaic power system employing a diversion charge controller as the sole means of regulating the charging of a battery shall be equipped with a second, independent means to prevent overcharging of the battery.

Substantiation: Diversion controllers are connected between the battery and a diversion load. This external circuit will have overcurrent protection. If the controller fails, if the diversion load is sized improperly, or if the overcurrent device opens during a fault or is manually operated, the battery charging process is no longer regulated. In systems using the inverter to divert excess battery current into the utility grid, the inverter may fail or the utility grid may go down.

An independent or backup charge regulating system is needed to improve the safety on those systems having diversion controllers. See related new proposal 690.72(B).

690.72(B) Diversion Charge Controllers–Overcurrent Protection and Ampacity

Proposal: Circuits containing a direct-current diversion charge controller and a direct-current diversion load shall comply with (1) and (2).

(1) The current rating of the diversion load shall be rated at least 150% of the current of the diversion charge controller.

(2) The conductor ampacity and the rating of the overcurrent device for this circuit shall be at least 150% of the maximum current of the diversion charge controller.

FPN: This requirement does not apply to ac or dc circuits using inverters that control the battery charging process by feeding power into the utility lines. Such circuits are used in several modes and must be sized and protected in a normal manner as required elsewhere in Article 690.

Substantiation: If the diversion load is undersized or if the overcurrent device in the circuit of a diversion charge controller opens from overloads due to excess diversion currents, the charge control process is lost and the battery may be over charged creating a safety hazard. Requiring the 150% rating on the diversion load, the overcurrent device, and the cable ampacity is consistent with other systems that could create hazardous conditions when overload protection is included. See Section 240.3(A). The 150% rating provides the necessary short-circuit protection.

The FPN is added for explanatory reasons. This requirement does not apply to ac or dc circuits using inverters that control the battery charging process by feeding power into the utility lines. Such circuits are used in several modes and must be sized and protected in a normal manner as required elsewhere in Article 690.

Code Corner Online

The Southwest Technology Development Institute Web site (www.nmsu.edu/~tdi) is now online. It has all of my *Code Corner* columns, an index of frequently asked questions, plus an Adobe Acrobat PDF copy of my manual, *Photovoltaic Power Systems and the National Electrical Code: Suggested Practices.*

Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems following the requirements of the *NEC,* feel free to call, fax, email, or write me. Sandia National Laboratories sponsors my activities in this area as a support function to the PV Industry. This work was supported by the United States Department of Energy under Contract DE-AC04-94AL8500. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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